SZ with LiteBIRD

Gemma Luzzi (SSDC - ASI)

On behalf of Post-PTEP SZ team

Post-PTEP SZ team

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What has been shown by SZ@PTEP:

- Results: despite lower angular resolution for cluster science, LiteBIRD provides full-sky coverage, higher sensitivity and a larger set of frequency bands as compared to Planck
- Hints: LiteBIRD will deliver the next (post-Planck) tSZ all-sky map
  - lower foreground contamination expected at large and intermediate scales
  - recover the large-scale diffuse electron temperature in the sky through the relativistic tSZ

Aim of the Post-PTEP SZ project

- The goal: assess the capabilities of LiteBIRD to map the hot gas in the Universe through the tSZ effect augmenting the current forecasts with realistic instrumental properties
- We rely on: dedicated temperature sky simulations combined with instrumental features from the IMO + tailored algorithms

1 short term project + 1 longer term project

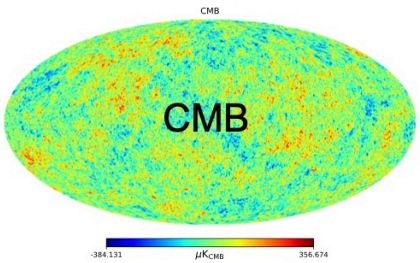
- Paper 1 (approved by IPB):
  Mapping the Hot Gas in the Universe with LiteBIRD
- Paper 2 (longer-term project):
  Applications of the LiteBIRD SZ map

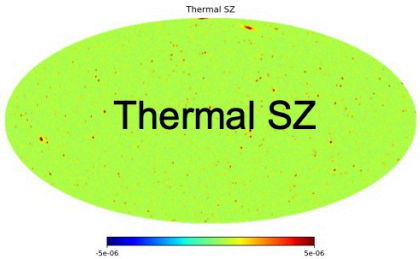
Mapping the Hot Gas in the Universe with LiteBIRD: what we did (and will go in paper 1 - writing phase)

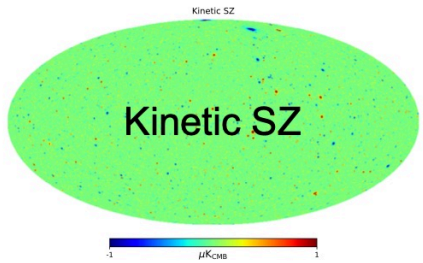
Overleaf: `https://www.overleaf.com/read/hgwcvgdwxyfr`

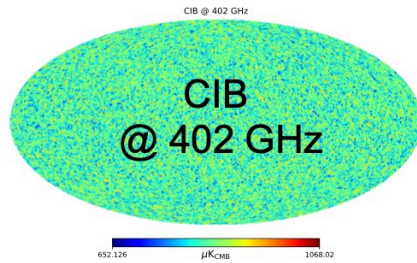
- LiteBIRD temperature map simulations
- LiteBIRD SZ all-sky y-map (component separation)
  - LiteBIRD-Planck combined y-map
  - SZ power spectrum and residuals
  - Cosmological parameter estimation
- Impact of systematics: 1/f noise

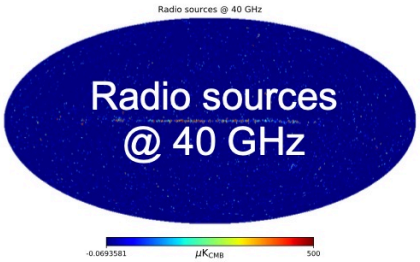
LiteBIRD temperature sky simulations

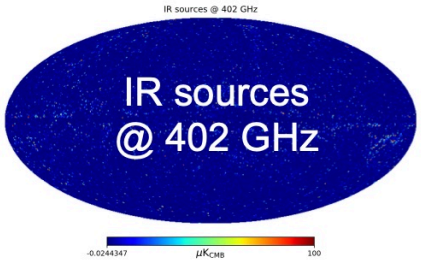


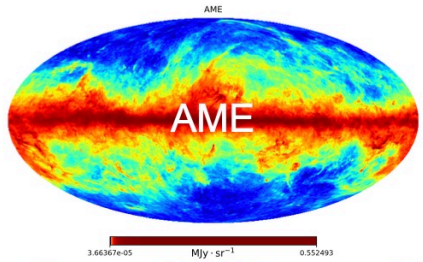


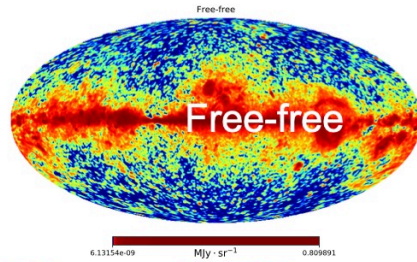


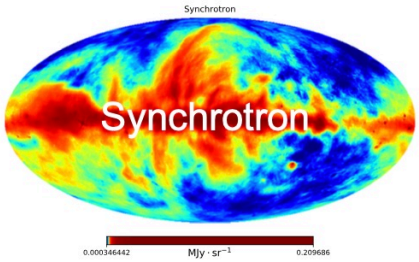


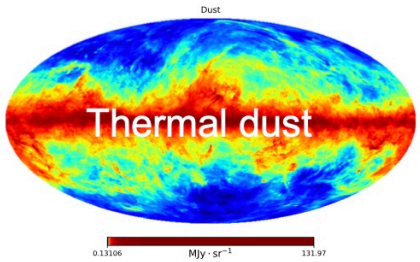








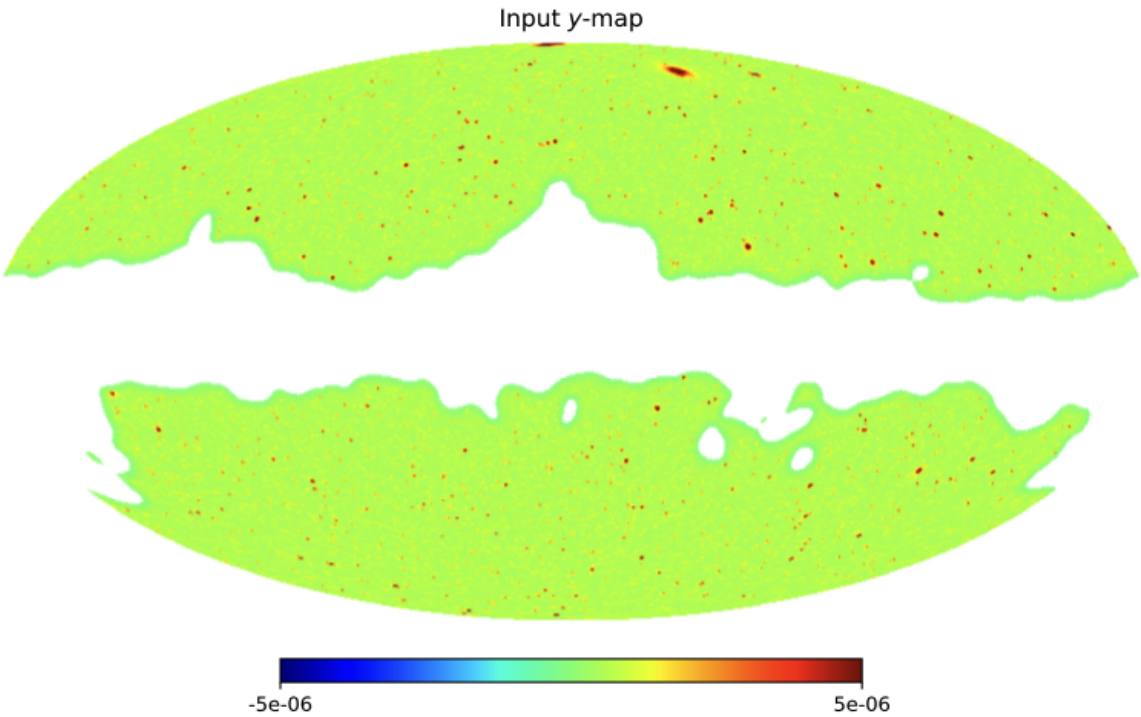




- Comprehensive sky (PTEP SZ)
- IMO (post-PTEP noise simulations):
  - white noise,
  - $1/f$ 30 mHz,
  - $1/f$ 100 mHz.

Component separation

Input y-map

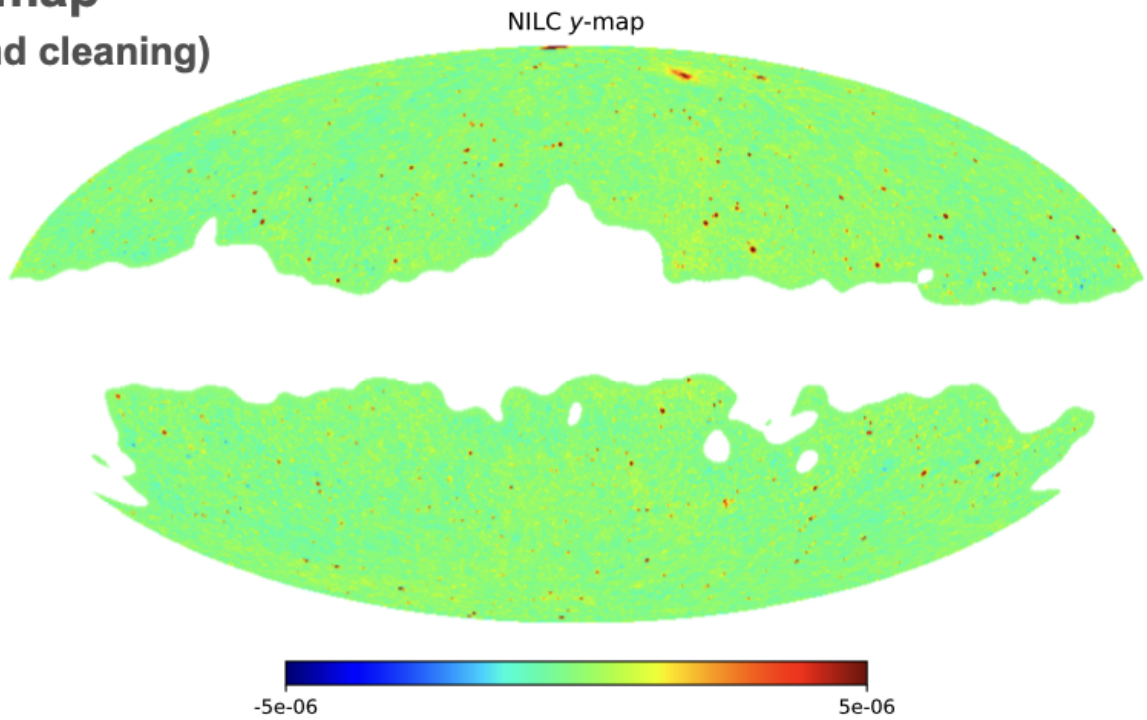


$\langle yy \rangle \sim \sigma_8^8$
$\langle yyy \rangle \sim \sigma_8^{11}$

Input thermal SZ y-map of the sky simulation smoothed to 30' angular resolution

Component separation

LiteBIRD y-map
(after foreground cleaning)



$\langle yy \rangle \sim \sigma_8^8$
$\langle yyy \rangle \sim \sigma_8^{11}$

Recovered LiteBIRD thermal SZ y-map at 30' angular resolution after foreground cleaning with NILC

Which main improvements wrt SZ@PTEP?

- Combining LiteBIRD and Planck channels for the y-map
- Integrating more sky
- Impact of 1/f noise
- Cosmological parameters constraints

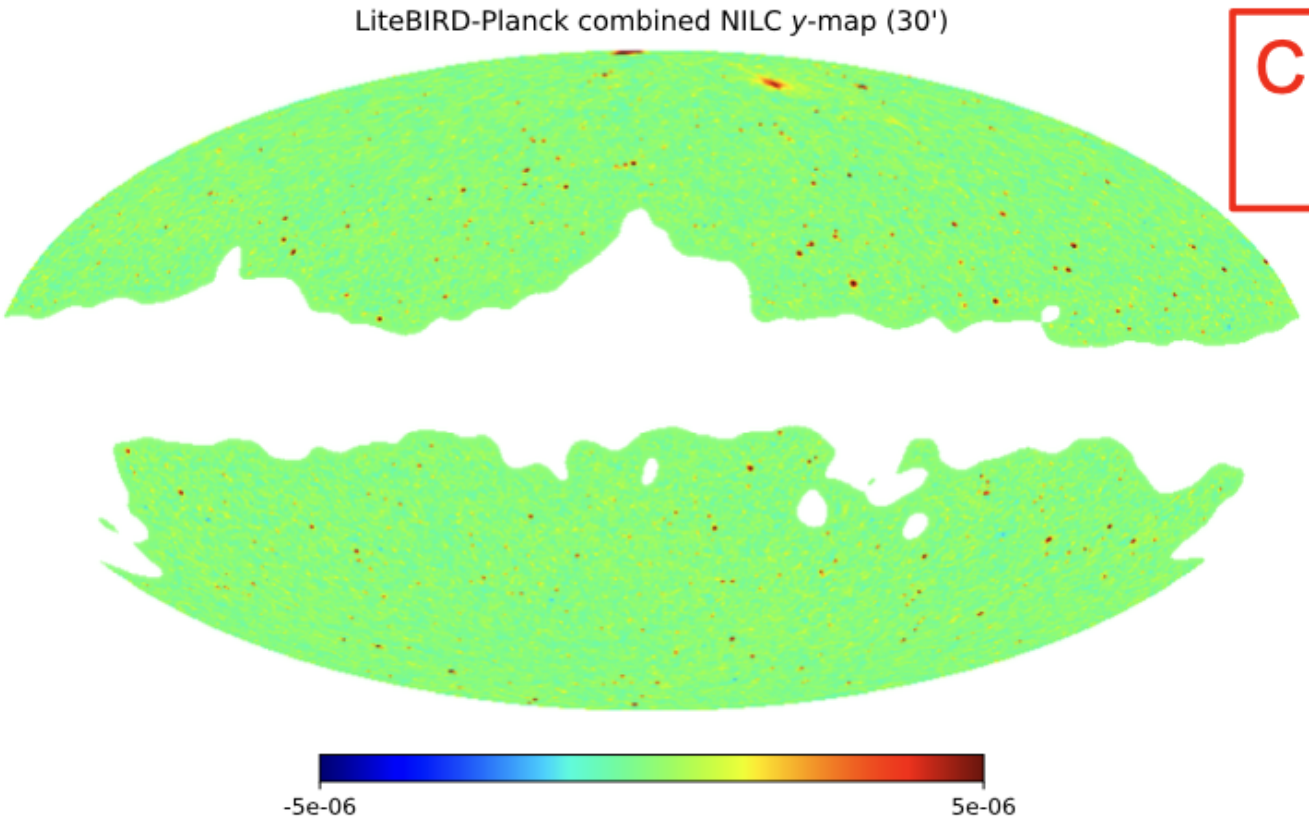
Combining LiteBIRD and Planck channels for the y-map

Taking simultaneous advantage from:

- The larger number of channels and sensitivity of LiteBIRD to clean foregrounds
- The higher resolution of Planck channels to recover compact SZ clusters beyond LB beam limits

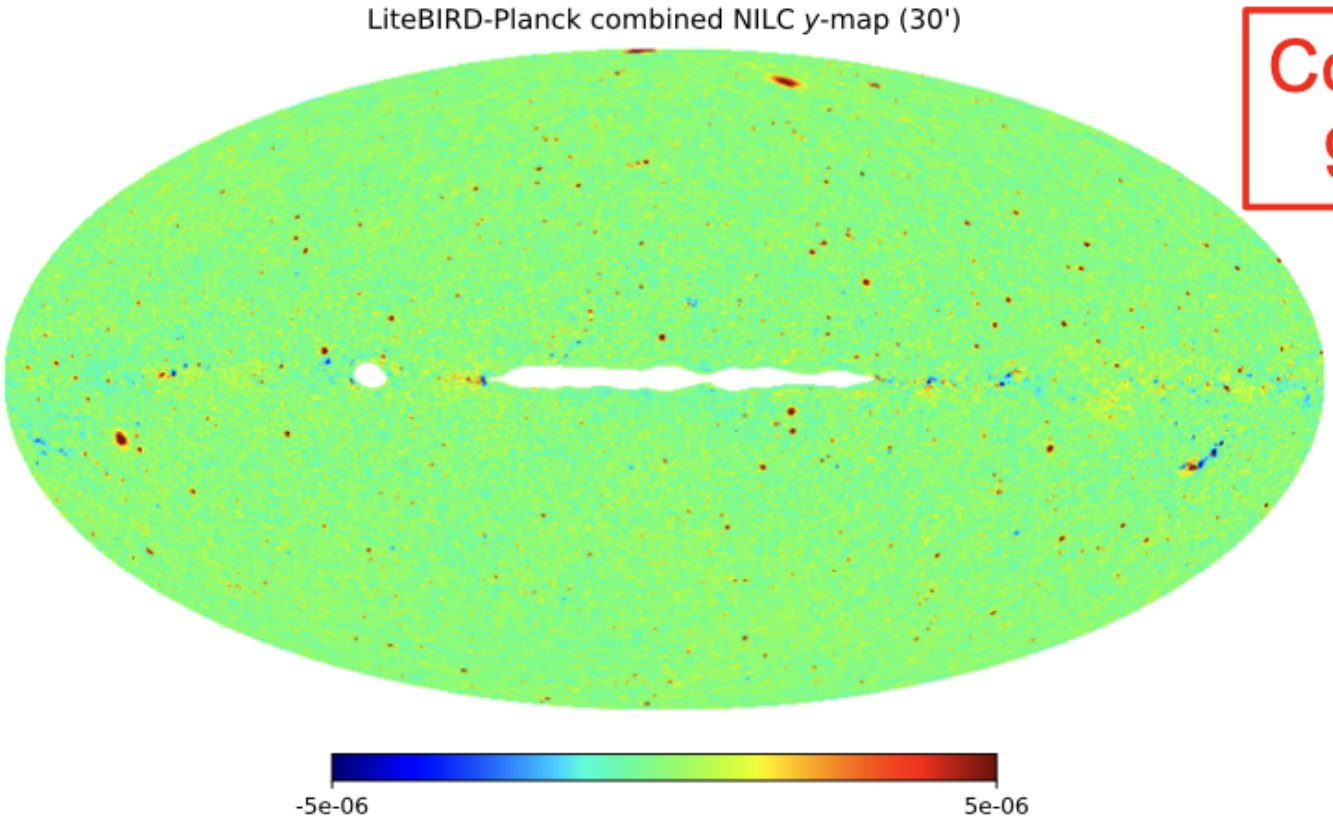
The best of both worlds!

LiteBIRD-Planck combined *y*-map (30') Comp. Sep. 70% sky



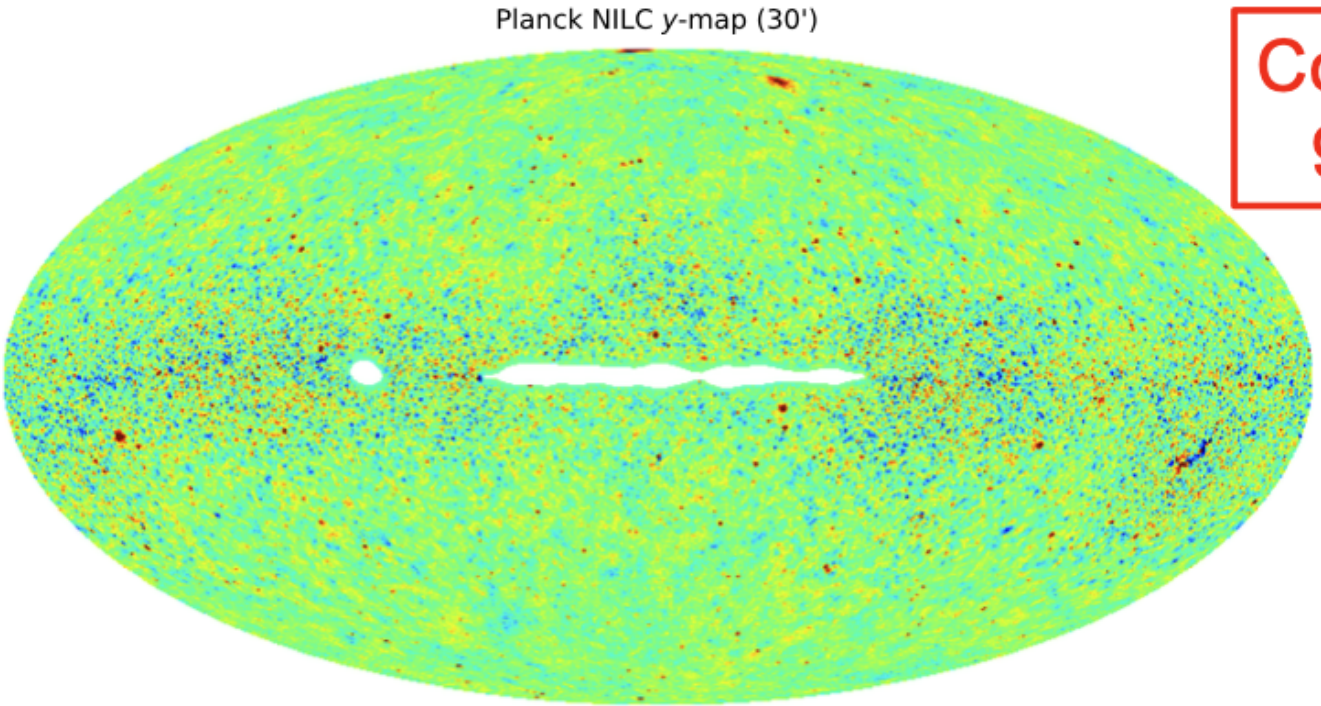
Comp. Sep. 70% sky

LiteBIRD-Planck combined *y*-map (30') Comp. Sep. 98% sky



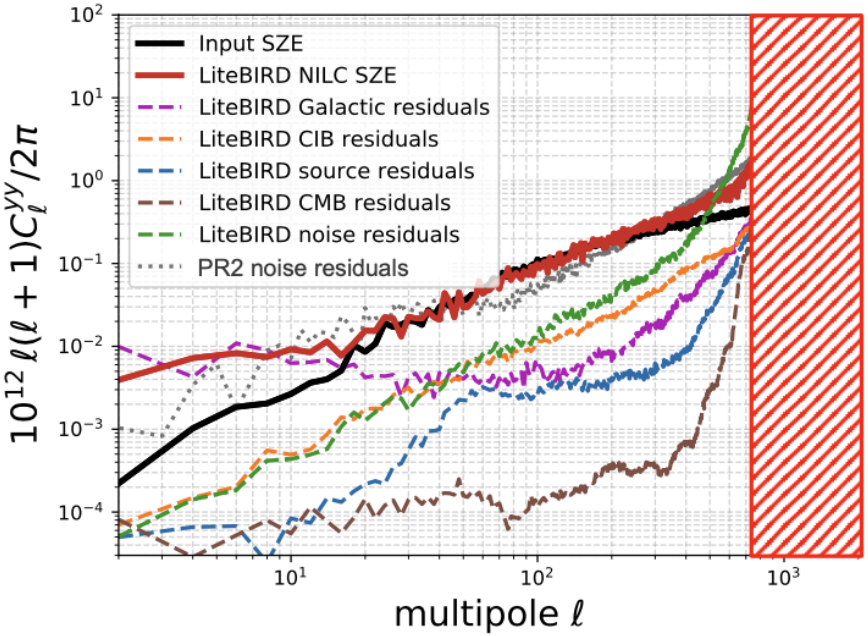
Comp. Sep.
98% sky

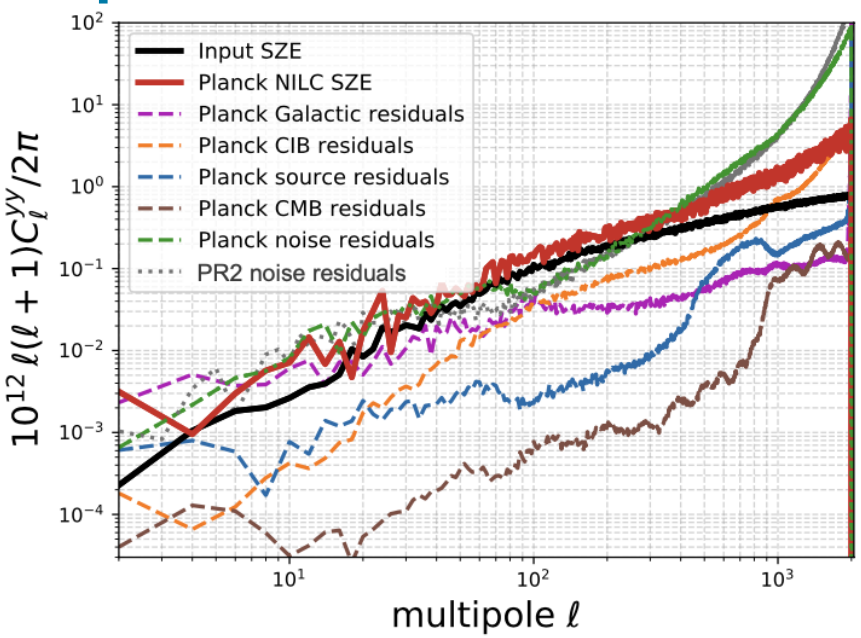
As a comparison: Planck *y*-map (30') Comp. Sep. 98% sky



Comp. Sep.
98% sky

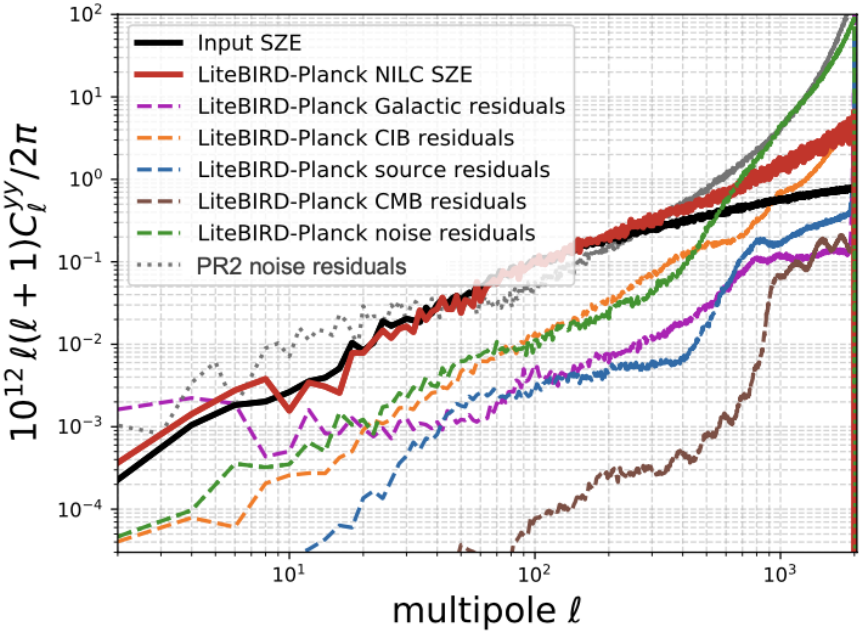
Looking to the Power Spectrum -1

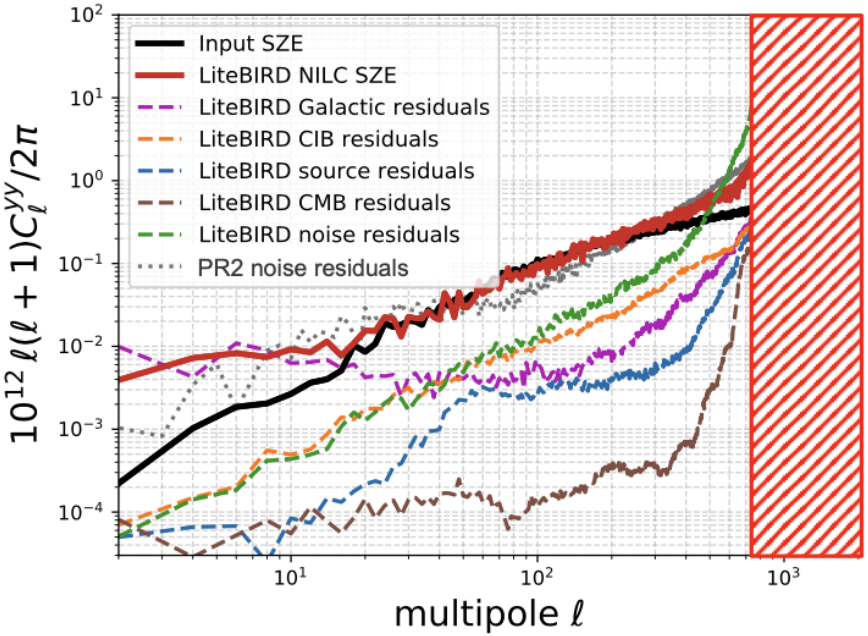




Left: Angular power spectrum of the recovered LiteBIRD thermal SZ y-map + angular power spectra of the residual foregrounds and noise, compared with the input SZ. Both agree well except at $l < 20$, which still shows residuals from the Galactic emission; however, such low multipoles suffer from large non-Gaussian cosmic variance error bars in any case. *Right*: *Planck* *y*-map power spectrum + angular power spectra of the residual foregrounds and residual noise.

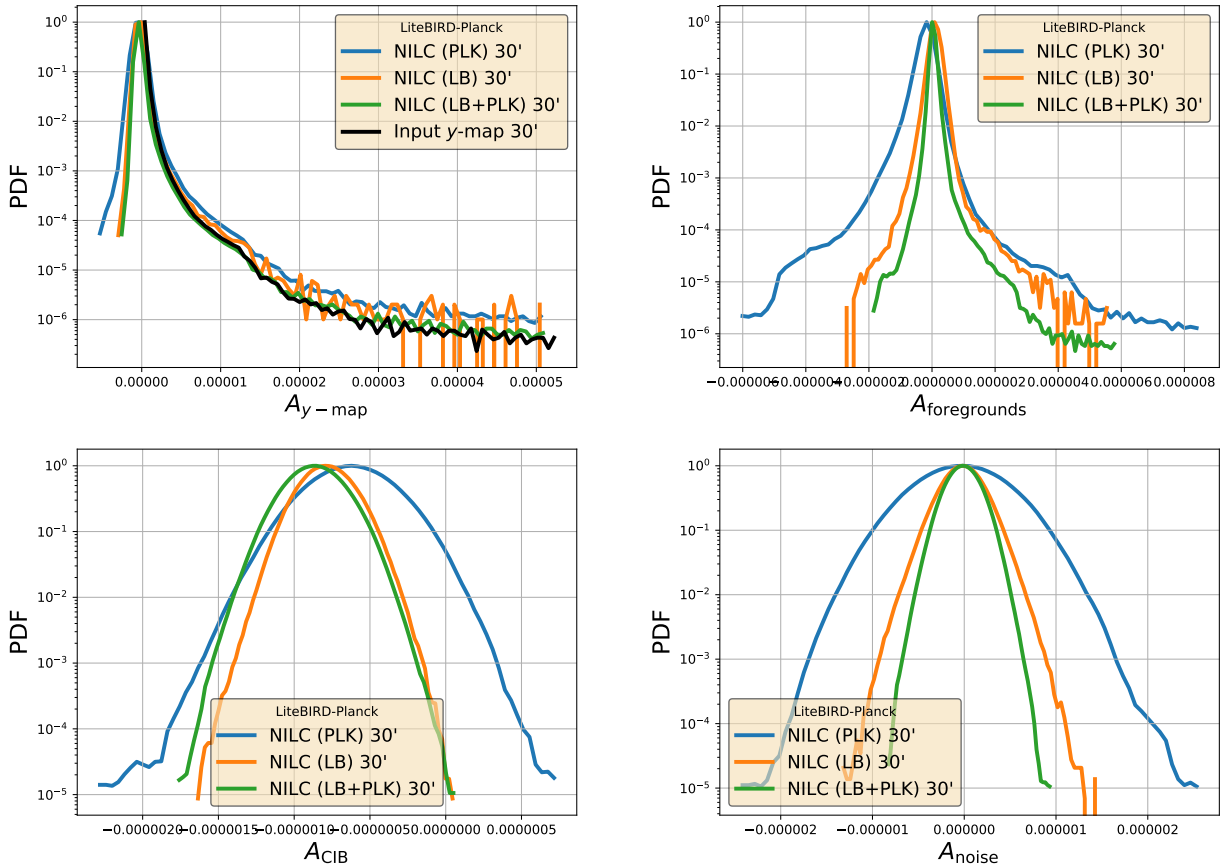
Looking to the Power Spectrum -2





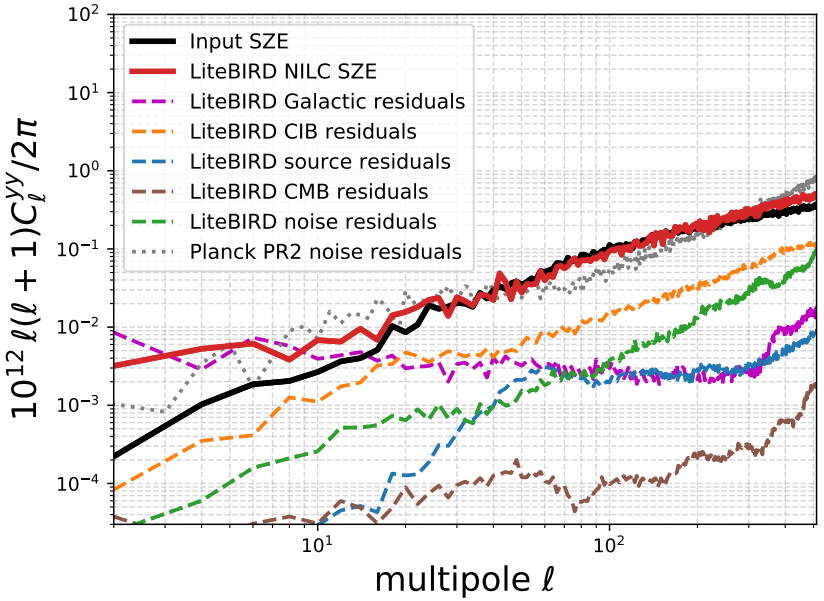
Left: Combined LiteBIRD-Planck *y*-map power spectrum + power spectra of the residual foregrounds and of residual noise.
Right: LiteBIRD *y*-map power spectrum, with projected foregrounds and noise power spectra.
The combination of LiteBIRD and Planck channels leads to lower foreground residuals and noise.

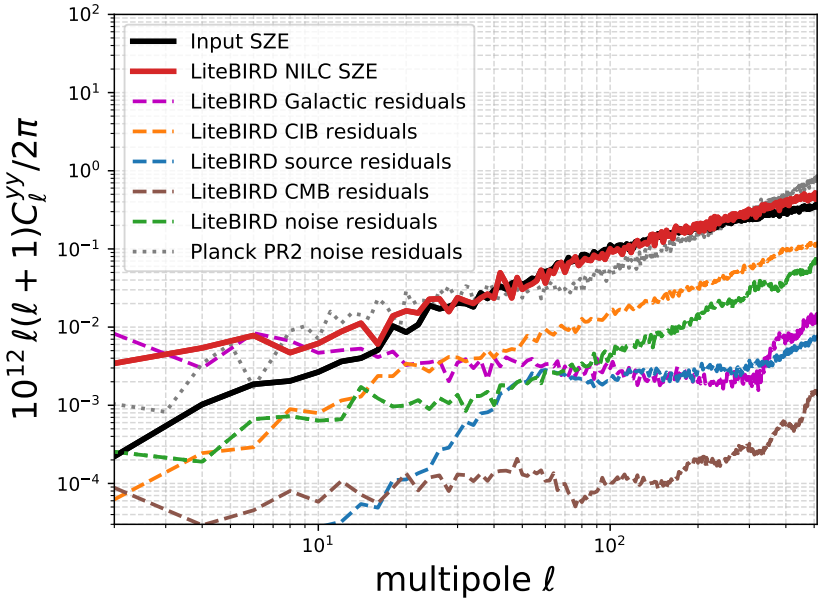
Looking to the one-point statistics



How LiteBIRD improves over *Planck* in terms of residual Galactic foreground contamination, CIB contamination and noise, and how the combination of LiteBIRD and *Planck* further reduces the residual contamination in the *y*-map

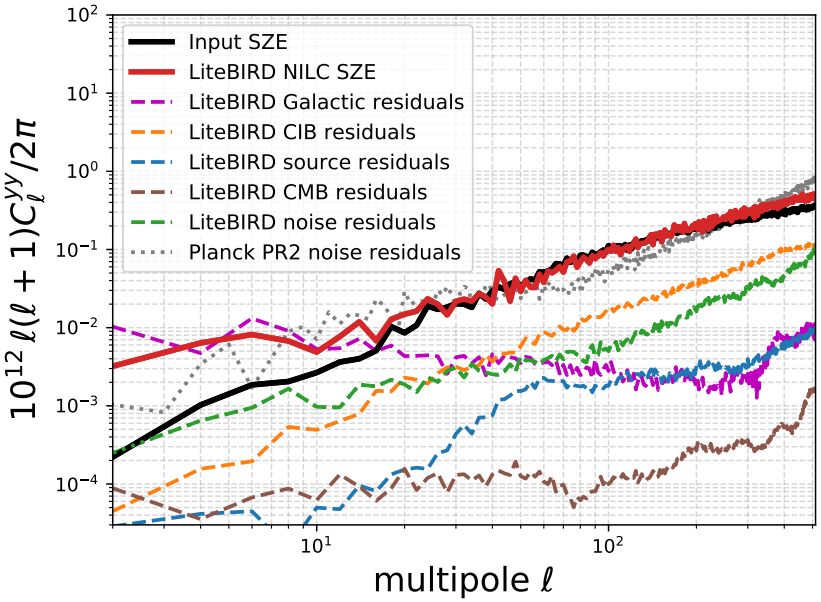
Impact of 1/f noise - no destriping -1

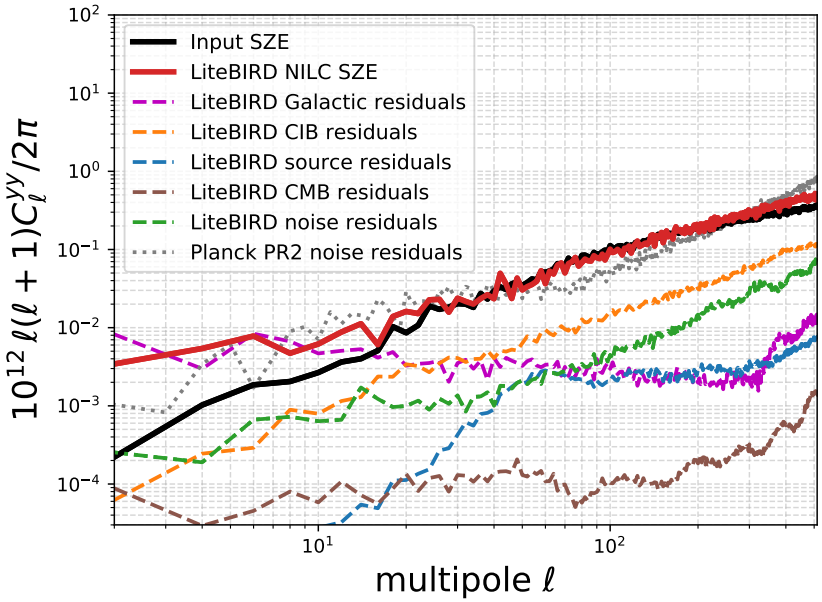




Left: White noise. *Right*: White noise + 1/f noise for $f_{knee} = 30$ mHz.

Impact of 1/f noise - no destriping -2

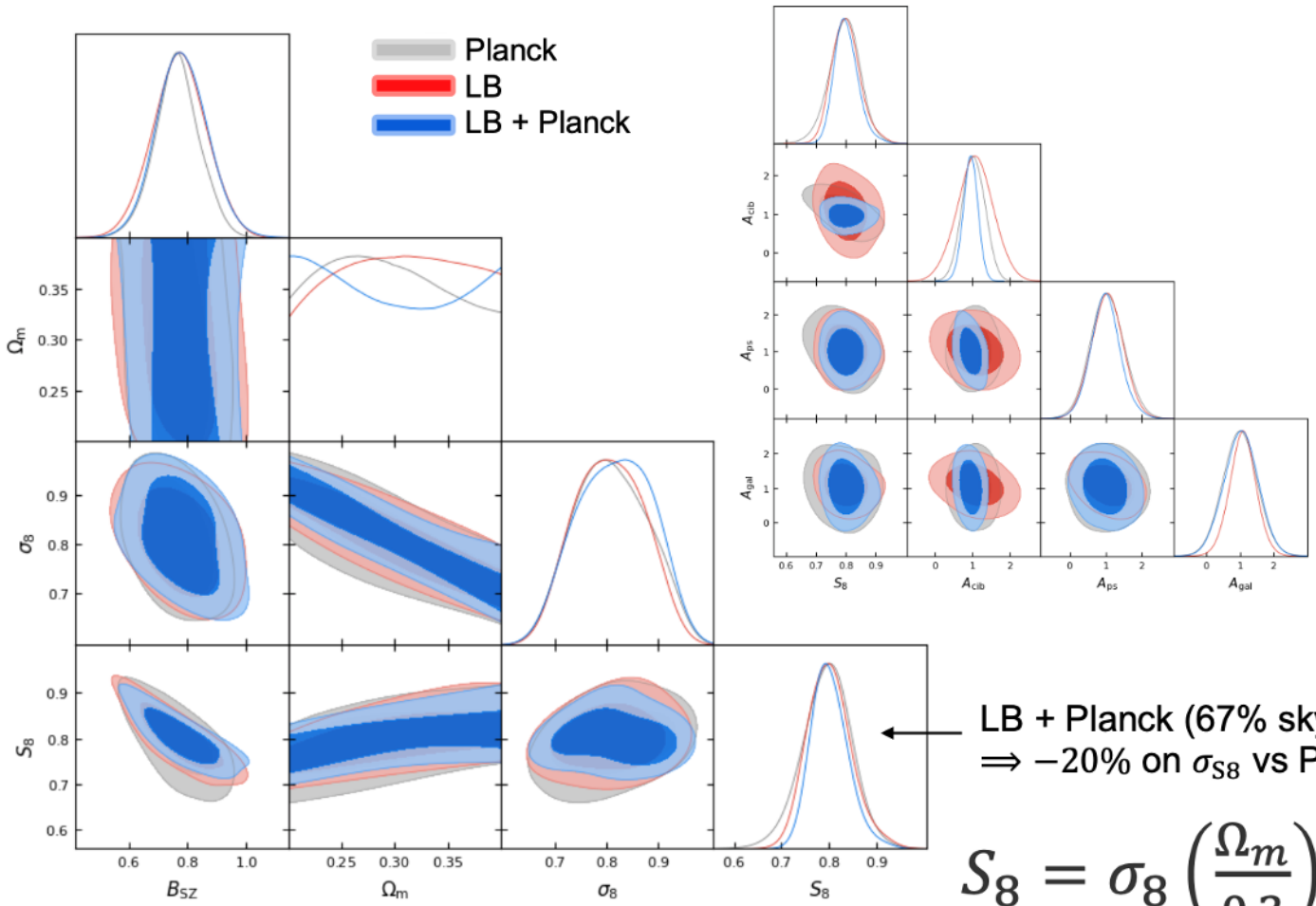




Left: White noise + 1/f noise for $f_{knee} = 100$ mHz. *Right*: White noise + 1/f noise for $f_{knee} = 30$ mHz. The impact of $1/f$ noise at low multipoles is still quite minor on the reconstructed LiteBIRD y-map even in the absence of destriping.

Cosmological parameters constraints

RESULTS : FULL NOISE (i.e. trispectrum contribution)



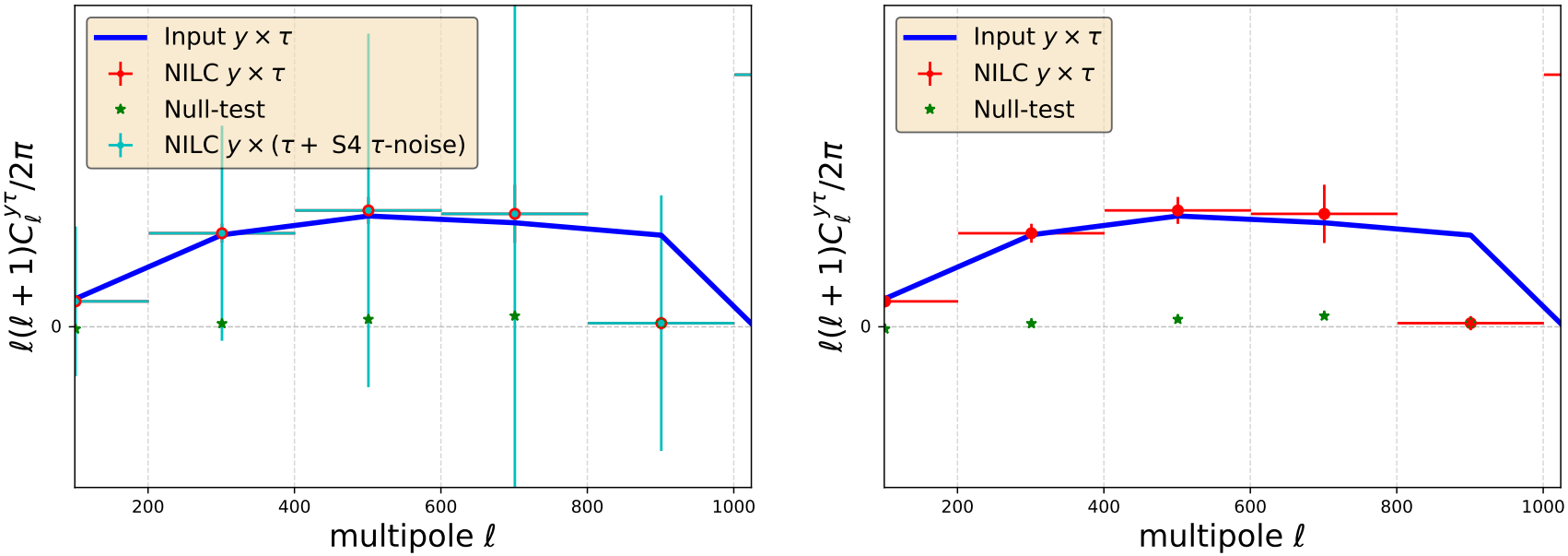
LB + Planck (67% sky)
$\Longrightarrow -20\%$ on σ_{S8} vs Planck (41% sky)

$$S_8 = \sigma_8 \left(\frac{\Omega_m}{0.3}\right)^{0.5}$$

What for next Post PTEP SZ paper?

- tSZ from patchy reionization
- Relativistic SZ effect and T_e
- CMB monopole y-distortion with tSZ?

tSZ from patchy reionization



Cross-power spectrum between the LiteBIRD SZ y-map and the inhomogeneous reionization optical depth τ-map from CMB-S4 in the case of a thermal SZ effect contribution induced by patchy reionization (single realisation).
Left: With CMB-S4 τ-noise. *Right*: For idealistic noise-free τ.

Relativistic SZ effect and T_e

Two main approaches:

- T_e with Constrained ILC
- T_e with parametric fit

LiteBIRD has a great potential for rSZ:

- sensitivity
- high frequency coverage
- narrow bandpasses

We just started, join to contribute!

CMB monopole y-distortion with tSZ?

- method first proposed by:
  R. Fabbri, F. Melchiorri, V. Natale, Astrophys. & Sp. Sci. 59, 223 (1978),
  Y. Rephaeli, Ap. J. 241, 858 (1980).
- applied by G. Luzzi et al EPJ Web Conf. 257, 00028 (2022) to forecast constraints on the primordial y-distortion of the CMB from distortion of the (local-Universe) tSZ effect.
- We are looking for a distortion of a distortion. Small signal for individual cluster's spectrum: we need stacking of $\sim 10^4$ clusters.
- Two approaches: Constrained ILC (partially explored) and parametric fit (to be done).
- Do we have the required sensitivity in presence of foregrounds?

CMB monopole μ-distortion with tSZ?

Measuring μ-Distortions from the Thermal Sunyaev-Zeldovich effect

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(Dated: May 18, 2023)

Forecasted constraints on μ-distortion using the tSZ spectrum for CMB-S4 experiment

SZ with LiteBIRD

- Check out our wiki page:
  `https://wiki.kek.jp/display/cmb/Project+Paper%3A+Mapping+the+Hot+Gas+in+the+Universe`
- Telecons: Thursday 10am UTC (fortnightly)
- Contact Gemma / Mathieu to contribute